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PLATTEVILLE HEATING RESULTS: HF RADAR OBSERVATIONS.(U)
JAN 79 R L SHOWEN, W B ZAVOLI N00014-75-C-0930

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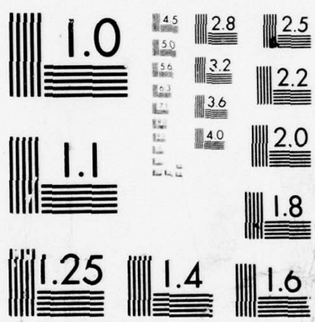

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Technical Report 43

January 1979

PLATTEVILLE HEATING RESULTS: HF RADAR OBSERVATIONS

By: R. L. SHOWEN W. B. ZAVOLI

Prepared for:

ROME AIR DEVELOPMENT CENTER (EEP)
AIR FORCE SYSTEMS COMMAND (AFSC)
HANSCOM AFB, MASSACHUSETTS 01731

CONTRACT N00014-75-C-0930
(NR 088-076)

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SRI International

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Approved by:

L. E. SWEENEY, JR., *Director*
Remote Measurements Laboratory

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Technology and Systems Development Division

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Measurements were made ~~by SRI International~~ during the Platteville ionospheric heating experiments, ~~of July and September 1978.~~ The measurements, made at the Wide Aperture Research Facility (WARF) ~~in California,~~ were of the HF-induced backscatter over Colorado. The standard Field-Aligned Scatter (FAS) was seen from ~16 to ~30 MHz, and an absolute cross section of 10^8 square meters was observed. Possible enhancements of direct scatter and round-the-world propagation through the heated region were noted. Attempts to measure elevated mode propagation from Australia to the heated region will be made in the near future.

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I INTRODUCTION AND SUMMARY

Results are presented of SRI International's participation in the Platteville, Colorado ionospheric modification experiments of July and September 1978. This work is sponsored by RADC and is carried out under the auspices of ONR contract no. N00014-75-C-0930. The Remote Measurements Laboratory of SRI International made coordinated observations using the Wide Aperture Research Facility (WARF) of the HF heater-induced ionospheric irregularities and their effects on certain propagation paths.

The WARF facility, located in California, is an over-the-horizon radar operating between 6 and 30 MHz. The ionospheric modification was produced by the Platteville 5 to 10 MHz, 1.5-MW heater facility.

Studies of ionospheric heating and propagation modification using the Platteville facility began in 1970 and are continuing. Several reports in the Ivory Coral and Prairie Smoke series describe these studies, and in the published literature two special journal issues (J. Geophys. Res., 75, 1970, and Radio Science, 9, November 1974) give the scientific results.

From the radio propagation standpoint, the most notable ionospheric effect is the creation of irregularities in the heater beam, irregularities which are aligned in the direction of the earth's magnetic field. These irregularities produce field-aligned scatter (FAS) of waves traversing the beam. The FAS is observed from ~5 to ~500 MHz but is stronger at the lower frequencies. The direction of scatter of a wave is in a cone such that the angle of reflection, with respect to the earth's magnetic field, is equal to the angle of incidence (see explanation of this geometry with diagrams in Fialer, 1974, and Stathacopoulos and Barry, 1974).

The current work measures the absolute cross section of the ionospheric "cloud" (the FAS) and the effects of cycling of the heater power. The work also appears to indicate enhanced radio wave propagation in both direct-scattering and round-the-world propagation modes.

Future work will include measurements of the elevation angle of the FAS cloud to permit more accurate specification of the WARF antenna gains and thereby providing a better estimate of the absolute cloud cross section. Additionally, the operation of a propagation path from Australia to Platteville may permit the interception of elevated-mode propagation by the heater and the scattering of this mode to the ground.

II MEASUREMENT METHOD

A. Experimental Geometry

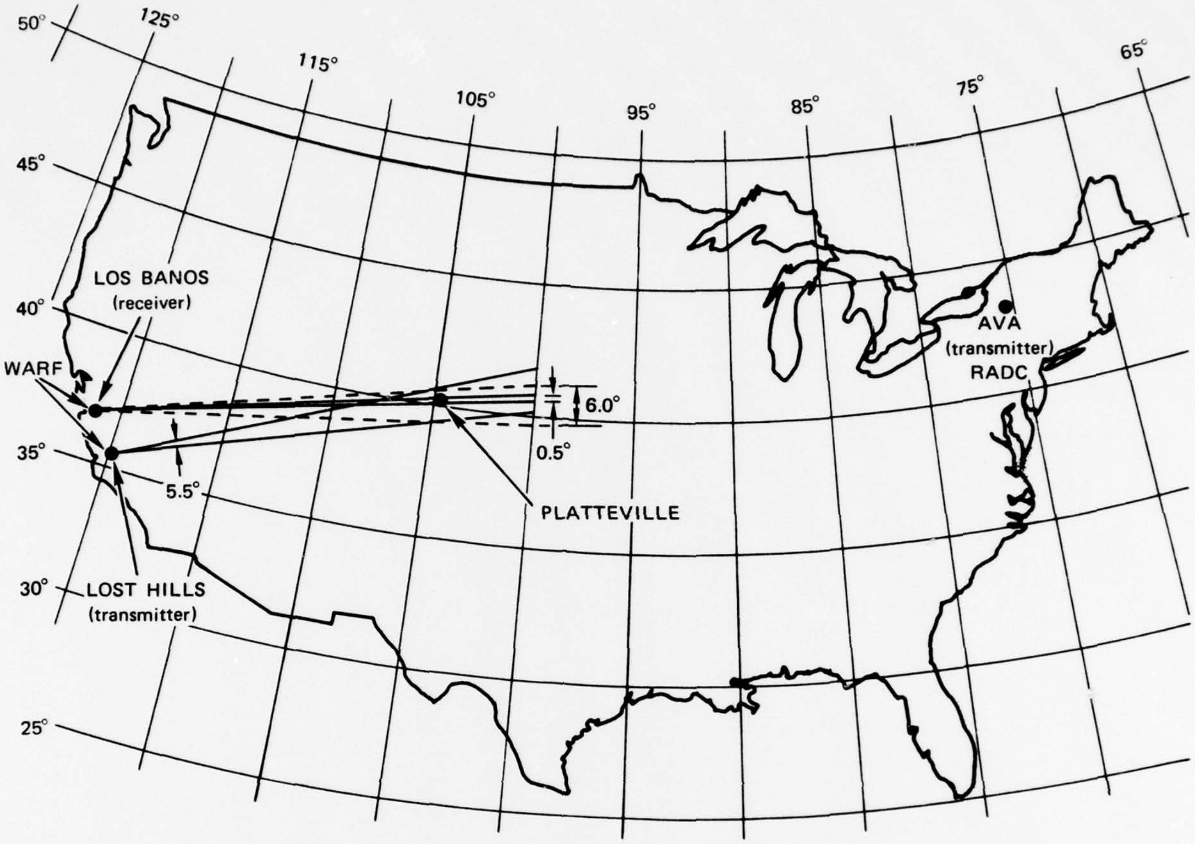
Figure 1 shows the geometry of the WARF/Platteville experiment. Typical WARF transmit and receive beams which are shown in Figure 1a illuminate the FAS cloud over the Platteville heater. Forward oblique soundings originating at the RADC facility at Ava, New York were also received at WARF. The WARF experimental configuration is described below.

To obtain azimuth profiles of the cloud's cross section, three of the WARF's half-degree receive beams were repetitively stepped across a series of contiguous bearings as the sounding frequency was varied. The dashed lines of Figure 1a show a scan sector of 6° centered over Platteville. Typically, azimuth profiles of 6° or 12° were obtained.

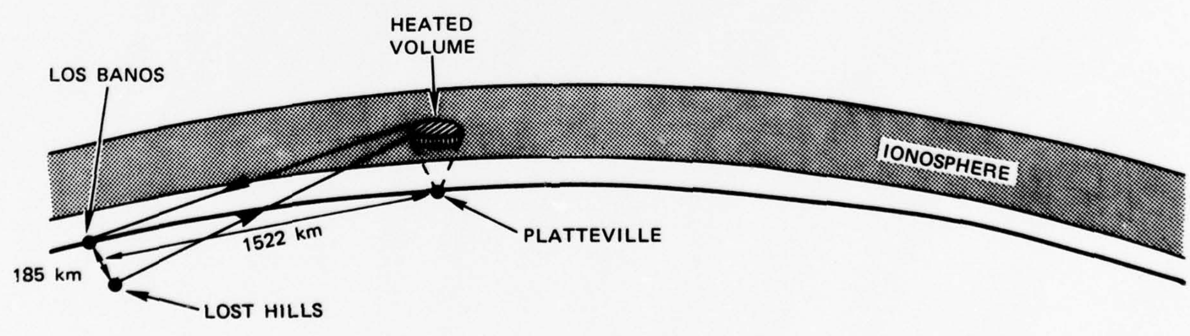
B. Sounding Transmissions

A linear swept-frequency continuous wave (SFCW) backscatter sounder was used to measure cloud echoes. After appropriate processing such a sounder waveform can measure signal echo strength as a function of time delay (slant range) and frequency. Both wide and narrow bandwidth SFCW waveforms were used. The widesweep soundings covered the 6- to 30-MHz band once every five minutes. These soundings were coordinated with similar transmissions from the RADC facility at Ava, New York, so that either backscatter or forward oblique soundings could be received at WARF.

Narrowband SFCW transmissions (typically of 25-kHz bandwidth) were used to continuously measure cloud echo strength and thus observe changes caused by stepwise variations in heater power levels.



(a) PLAN VIEW



(b) ELEVATION VIEW

FIGURE 1 WARF-HEATER EXPERIMENT GEOMETRY

C. Data Collection

A block diagram of the WARF receiving, processing, and data recording system used for this experiment is shown in Figure 2. A hybrid spectrum analyzer provides real-time widesweep backscatter soundings to verify proper functioning of equipment and to aid in selecting transmission and recording parameters. Such an ionogram is reproduced in Figure 3. Parameters used in the transmission and processing of this ionogram are listed in Table 1. Calibration markers are superimposed at intervals of 1 ms in time delay and 1 MHz in frequency (10 s in time). Identifiable signatures in the sounding include the F-layer land backscatter returns and direct cloud echoes. The 2-MHz periodic structure seen in the cloud echo is created because the receive antenna was stepped in azimuth every 2.5 s, repeating the sequence every 20 s (hence every 2 MHz).

Digital recordings were collected as shown in the block diagram of Figure 2 so that accurate measurements of cloud cross sections could later be computed. The receivers were operated with automatic gain control (AGC) to accommodate the very large variation in received signal strength typical of widesweep soundings. To calculate absolute cross sections, the three receivers were slaved to the same gain control circuit, and the instantaneous receiver gain was digitally recorded.

To reduce data recording and processing requirements, the digital records were limited to an 8-ms range coverage, which was more than adequate because the cloud slant range echo was typically less than 2 ms. Also, digital spectra were computed for each receive channel in real time and only the spectral magnitudes were recorded. The parameters used for this processing are listed in Table 1. Each 25-kHz (250-ms) segment was Fourier transformed, yielding a spectra with 40-μs time-delay resolution. Ten such spectra (2.5 s) were recorded for each beam position.

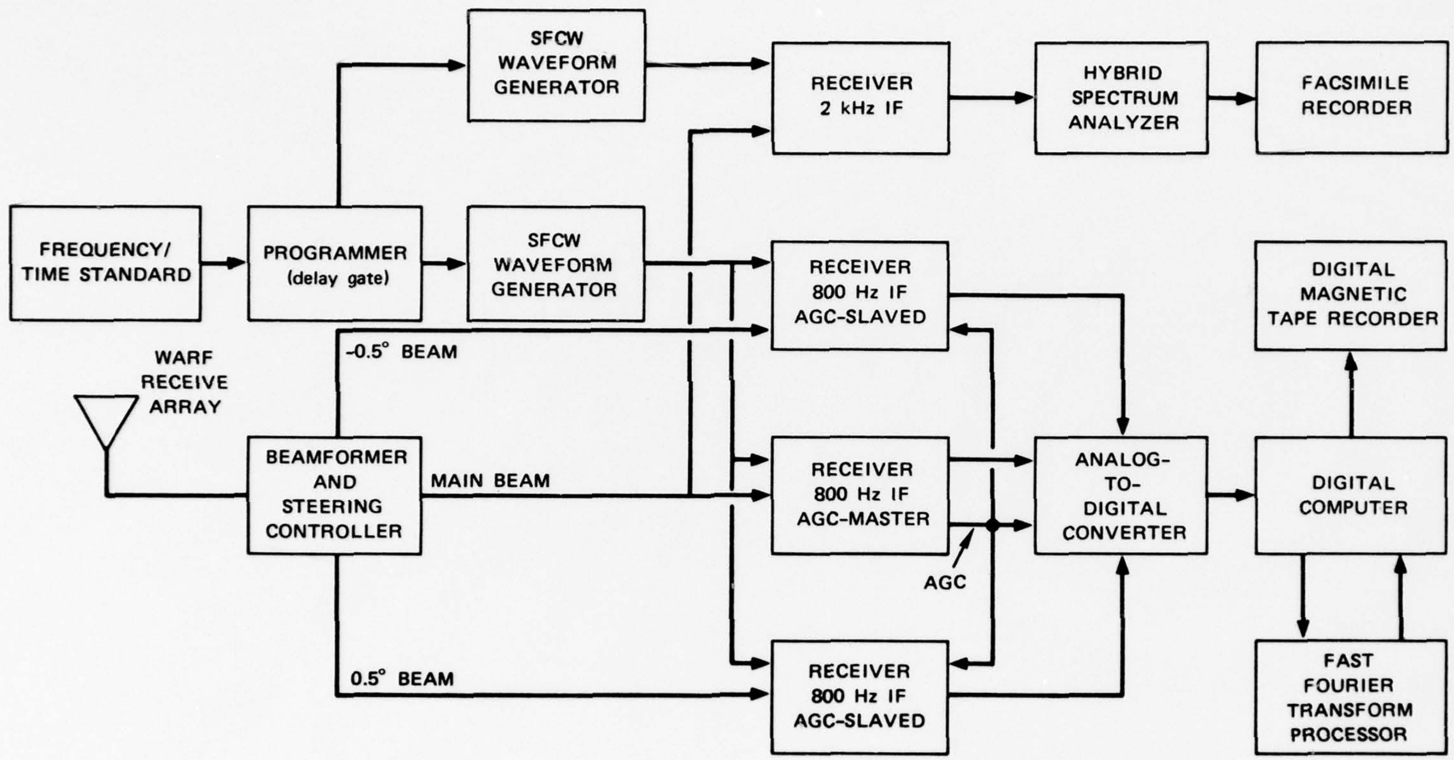


FIGURE 2 WARF RECEIVING AND RECORDING SYSTEM

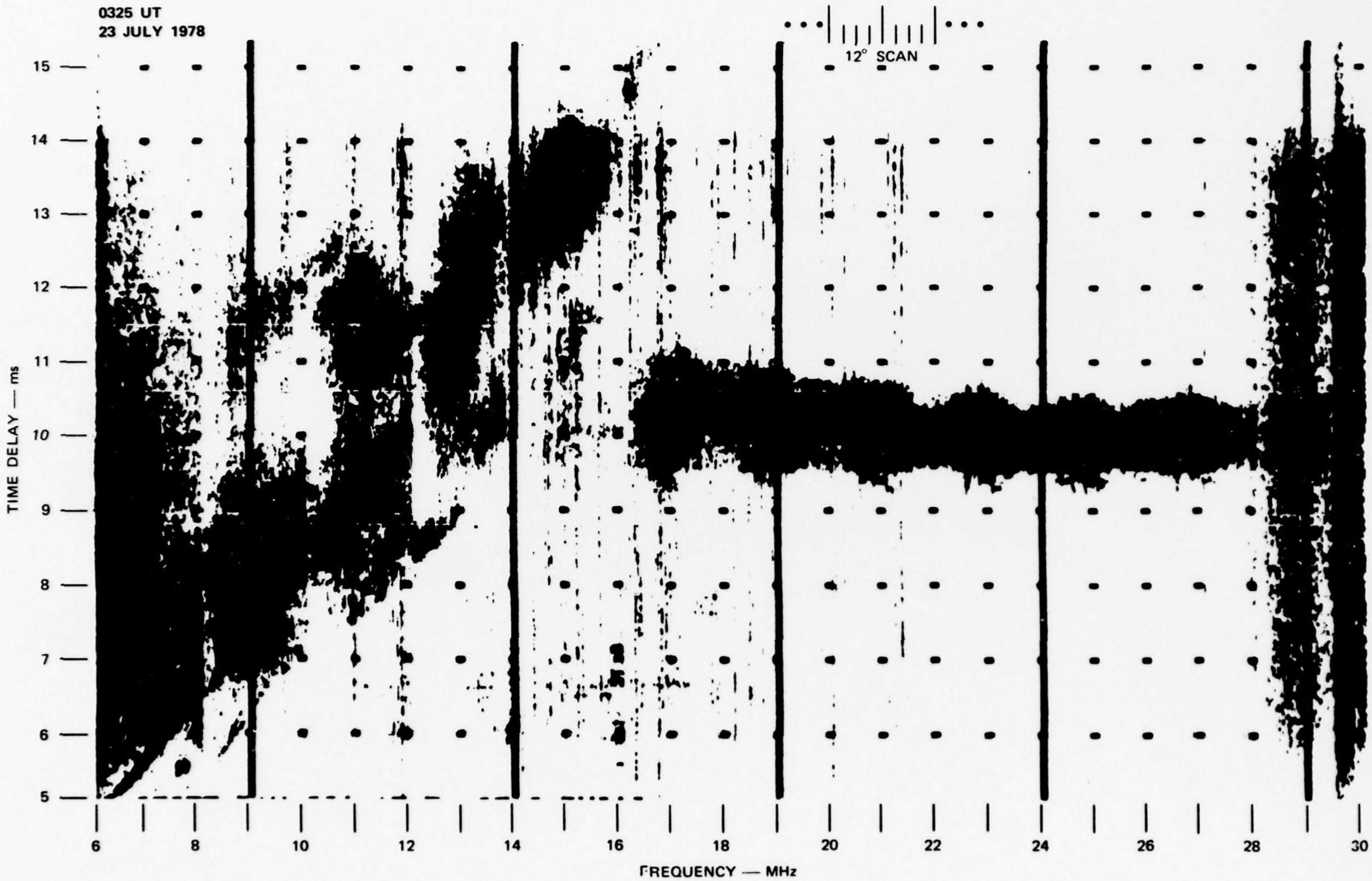


FIGURE 3 WARF BACKSCATTER SOUNDING SHOWING DIRECT SCATTER FROM HEATED REGION

Table 1

WIDE SWEEP BACKSCATTER SOUNDING PARAMETERS

Transmission Format	
Waveform	SFCW
Limits	6 to 30 MHz
Sweep Rate	100 kHz/s
Repetition Rate	5 min
Analog Processing	
Receiver Bandwidth Analyzed	1 kHz
Time Delay Coverage	10 ms
Coherent Integration Time	0.5 s
Transmitted Bandwidth per Spectrum	50 kHz
Analyzer Resolution	20 μs
Output	Facsimile display
Digital Processing Parameters	
Receive Bandwidth	870 Hz
Sample Rate*	2048 Hz/channel
Coherent Integration Time	0.25 s
Transform Size	512 points
Time-Delay Coverage	~8.7 ms
Time-Delay Resolution	40 μs
Output	Spectrum magnitude (floating point format on digital magnetic tape)

*Slightly higher than Nyquist rate

This recording format proved extremely flexible. The same format was used for the various experimental observations:

- Azimuth and frequency profiles of direct backscatter cross sections from the cloud
- Forward-oblique sounding from Ava, New York
- Round-the-world (RTW) propagation echoes
- Narrowband sounding providing continuous monitoring of the cloud echo.

Results from these experiments are described in the next section.

III TEST RESULTS

Two ionospheric heating experiments were conducted in 1978. SRI participated from 19 to 23 July and from 18 to 22 September. In addition, prior to the July tests round-the-clock soundings were collected on several occasions to determine the extent of natural RTW over the Los Banos to Platteville great circle path. Results from the July and September tests are discussed separately.

A. July Heating Experiments

1. RTW Propagation

When observing RTW signals, WARF is operated in a slightly different configuration from the backscatter sounding system described earlier. Transmitted waveforms and antenna bearings remain identical. However, instead of receiving backscatter from the heated region, the WARF transmitting array is steered to the reciprocal of the bearing to Platteville. The SFCW waveform at the receive site is delayed 135 ms to receive signals having the appropriate time delay for the (first trip) round-the-world propagation path.

To determine what normal modes of RTW occur along the Los Banos to Platteville great circle path, soundings were recorded around the clock on eight occasions prior to the first heating experiment. These soundings were taken using a 1-kW transmitter (instead of 20 kW) to limit staffing requirements. Figure 4 indicates those times when RTW propagation was observed. Although the precise signature of the RTW signal varied, it generally appeared distributed in time delay by about 1 or 2 ms. These signals were observed from 13 to 23 MHz, but most often their frequency extent was confined between 16 and 20 MHz.

Full-power (20 kW) soundings configured for RTW observations were made at various times during the July heating experiment. The only

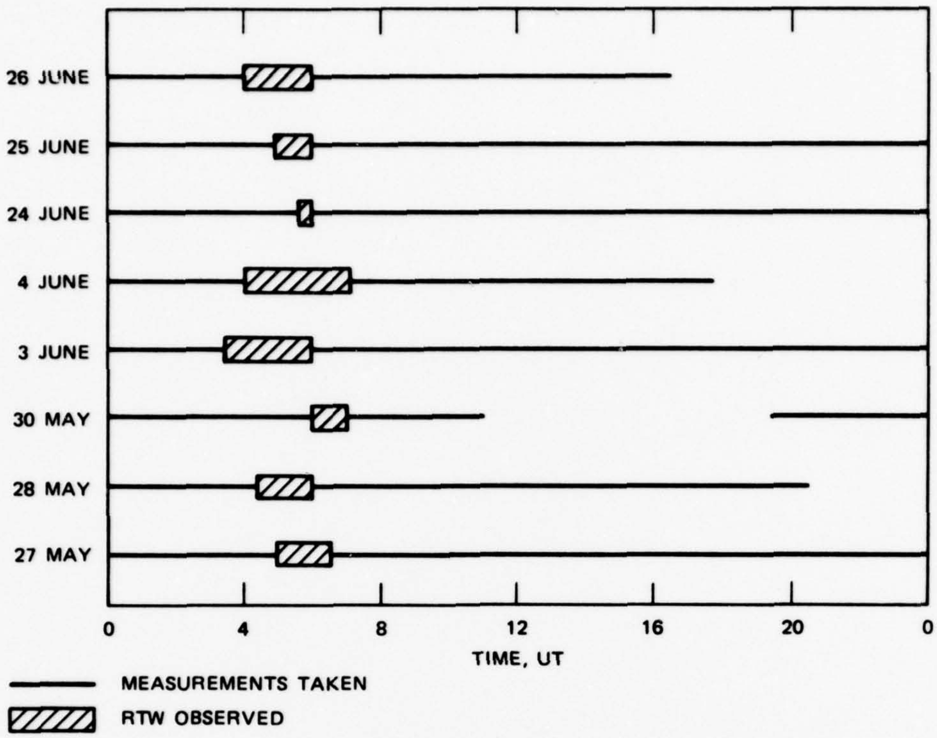


FIGURE 4 OBSERVATIONS OF RTW OVER GREAT CIRCLE PATH DEFINED BY LOS BANOS, CALIFORNIA AND PLATTEVILLE, COLORADO

RTW signals observed occurred between 0400 to 0510 UT 23 July. During this time period, the heater transmissions were cycled on for ten minutes and off for ten minutes. There are no apparent differences between the RTW signals of the on records and those of the off records. In addition, the RTW signal characteristics are not significantly different from those of signals observed prior to the heater experiment.

2. Measurement of the FAS Cloud Absolute Cross Sections

The radar backscatter cross section, σ_c, of the cloud can be calculated through the use of the radar equation:

$$S = \frac{P_t G_t}{4\pi R^2} \times \frac{\sigma_c}{4\pi R^2} \times \frac{G\lambda^2}{4\pi} \times \frac{1}{L} \qquad (1)$$

where

$S \equiv$ received signal strength

$P_t \equiv$ transmitted power

$G_t \equiv$ transmit antenna gain

$G \equiv$ receive antenna gain

$R \equiv$ slant range

$\lambda \equiv$ sounder wavelength

$\sigma_c \equiv$ radar cross section of the cloud

$L \equiv$ excess loss.

Because excess losses [designated L in Equation (1)] cannot be controlled or directly measured by the radar, it is convenient to define an apparent cross section, $\hat{\sigma}_c$, which includes this loss term. Thus Equation (1) can be rewritten for direct computation as:

$$\hat{\sigma}_c = \frac{\sigma_c}{L} = S \times \frac{4\pi R^2}{P_t G_t} \times \frac{4\pi}{G\lambda^2} \times 4\pi R^2 \quad . \tag{2}$$

Clearly σ_c *can be accurately calculated only if the received echo strength*, S, is accurately measured and the remaining radar specifications are well-known. Tables 2 to 4 provide WARF specifications at various HF frequencies and elevation angles. These tables show that system gain rapidly varies with elevation, especially at the low angles used in this geometry. For the initial heater experiments described here, raytracing (using electron profiles provided by a sounder near Platteville) was employed to estimate elevation angles. For subsequent tests it is hoped that the elevation angles will be measured directly.

Measurements of the received signal strength were obtained from digital records of the cloud echo in the backscatter soundings. Figure 5 presents an example of the output of these digital records. These plots represent the logarithm of received power as a function of time delay for three simultaneously received bearings, and are computed from the noncoherent average of 10 spectra taken at a particular bearing. Thus the plot is an average over 2.5 s in time and 25 kHz in HF frequency. Each of the plots of Figure 5 can be viewed as an amplitude crosscut of a widesweep

Table 2

TRANSMITTER POWER (P_t)

f (MHz)	λ (m)	P_t (dBW)
8	37.5	43
10	30.0	43
12	25.0	42
14	21.43	40
16	18.75	39
18	16.67	39
20	15.0	40
22	13.64	40
24	12.5	41
26	11.54	41
28	10.71	40
30	10.0	33

Table 3

ABSOLUTE GAIN OF TRANSMIT ARRAY, G_t (dBi)

(The gains are accurate to within ±2 dB.)

f (MHz)	λ (m)	Elevation Angle									
		1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
8	37.5	-0.5	8.2	11.7	12.6	13.5	14.0	14.2	14.3	14.4	14.5
10	30.0	0	9.0	13.0	15.0	15.5	16.0	16.2	16.3	16.0	16.1
12	25.0	1.0	10.0	14.0	16.0	17.5	17.7	17.9	18.0	17.7	17.5
14	21.43	2.0	10.5	14.5	16.6	17.6	18.2	18.3	18.1	17.7	17.3
16	18.75	3.0	11.0	15.0	17.2	18.7	18.6	18.5	18.2	17.8	17.2
18	16.67	4.0	11.5	15.5	17.8	19.3	19.0	18.7	18.3	17.9	17.1
20	15.0	5.0	12.0	16.0	18.5	20.0	19.5	19.0	18.5	18.0	17.0
22	13.64	6.0	13.0	17.0	19.4	21.0	20.5	20.0	19.5	19.0	18.0
24	12.5	7.0	14.0	18.0	20.3	22.0	21.5	21.0	20.5	20.0	19.0
26	11.54	6.0	12.0	16.0	17.3	19.0	18.5	18.0	17.5	17.0	16.0
28	10.71	5.0	9.0	12.0	14.3	16.0	15.5	15.0	15.9	19.4	14.5
30	10.0	3.0	4.5	8.0	10.3	12.0	12.8	13.2	13.8	14.2	14.5

Table 4

ABSOLUTE GAIN OF LOS BANOS RECEIVING SYSTEM, G (dBi)

(The gains are accurate to within ±2 dB.)

f (MHz)	λ (m)	Elevation Angle									
		1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
6	50.0	-14.9	-8.5	-5.0	-2.7	-1.1	0	0.9	1.5	2.1	2.5
8	37.5	2.1	8.3	12.0	14.4	16.2	17.4	18.4	19.2	19.8	20.3
10	30.0	9.4	15.5	19.2	21.7	23.5	24.9	26.0	26.9	27.5	28.1
12	25.0	15.0	21.0	24.6	27.1	29.0	30.4	31.6	32.5	33.3	33.9
14	21.43	16.7	22.5	26.0	28.5	30.4	31.9	33.1	34.1	34.9	35.6
16	18.75	13.8	19.5	22.9	25.3	27.2	28.7	29.9	30.9	31.7	32.4
18	16.67	13.3	18.8	22.1	24.4	26.2	27.7	28.9	29.9	30.8	31.5
20	15.0	12.8	18.3	21.4	23.6	25.4	26.8	28.0	29.0	29.8	30.6
22	13.64	11.6	17.0	20.0	22.1	23.9	25.0	26.2	27.1	28.0	28.7
24	12.5	8.3	13.7	16.7	18.7	20.2	21.4	22.4	23.3	24.0	24.7
26	11.54	5.3	10.7	13.7	15.6	17.0	18.0	19.0	19.8	20.4	21.0
28	10.71	1.2	6.1	9.7	11.5	12.9	13.9	14.7	15.3	15.8	16.7
30	10.0	-4.9	0.6	3.6	5.6	6.9	7.9	8.6	9.1	9.4	9.7

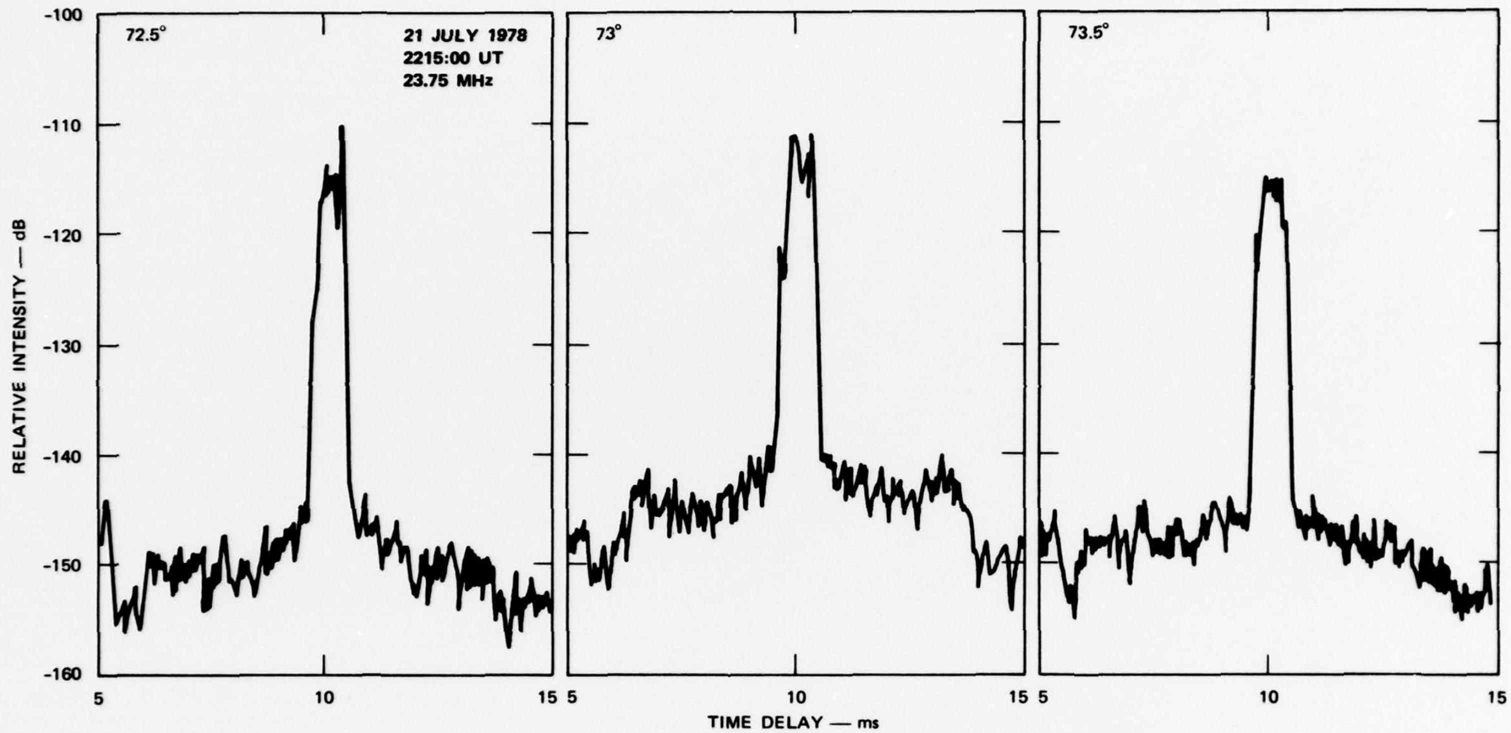


FIGURE 5 INTENSITY OF DIRECT SCATTER FROM HEATED REGION

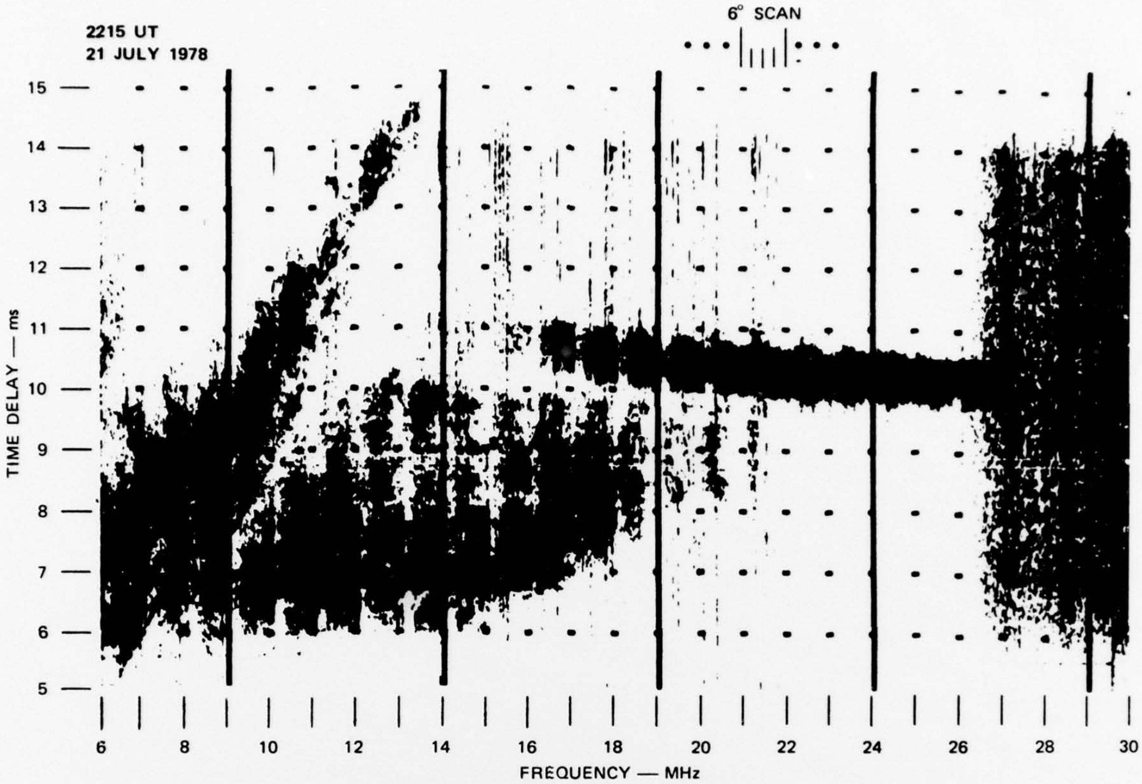
backscatter sounding for a particular sounding frequency. Three such plots, one for each of the three half-degree receive beams are obtained for each 25-kHz segment. The antenna bearing is changed for the next 25-kHz segment in the sounding. Thus, received signal strength can be measured from these recordings at various bearings and sounding frequencies.

The total signal strength (integrated over the range extent of the cloud) can be substituted into Equation (2) along with appropriate system parameters found in Tables 2 to 4 to produce a two-dimensional matrix of cloud cross sections. An elevation angle of 10° was assumed, on the basis of raytracing analysis.* This procedure was applied to three separate soundings taken during the July series of tests. Figures 6(a), 7(a), and 8(a) reproduce the soundings, and Figures 6(b), 7(b), and 8(b) display the resulting matrices. The soundings of Figures 6(a) and 7(a) were taken with a 6° scan sector (1 MHz revisit). For these two soundings the heating frequency was 6.95 MHz which was slightly above the local f_oF_2 measured at 6.9 MHz.

The cross-section profiles for all three matrices appear similar--despite differences in heating frequencies relative to the local f_oF_2. The 6° scans are too narrow to measure the total azimuthal profile, but from the 12° scan [Figure 8(b)] the 10-dB azimuthal width is computed as 6.3°. For a slant range of 1590 km to the center of the cloud this azimuthal width corresponds to a cross range extent of 175 km, which is remarkably close to the measured range depth of 180 km. The total cloud cross section [right column in Figures 6(b), 7(b), and 8(b)] was computed by summing across the azimuth profile and correcting for beam overlap. These cross section estimates generally agree with previous cloud cross-section measurements at HF of 70 to 80 dBsm (Fialer, 1974).

Further studies of the three cross-section matrices of Figures 6-8 reveal that for most frequencies the peak cloud echo is consistently found to be 1° to 1.5° south of the great circle bearing to Platteville. However, as the sounding frequency approaches the upper limit for heater

*The actual elevation angle may have deviated from that assumed by several degrees. Since the system gain changes with elevation angle, this error can introduce an additional uncertainty of several dB.

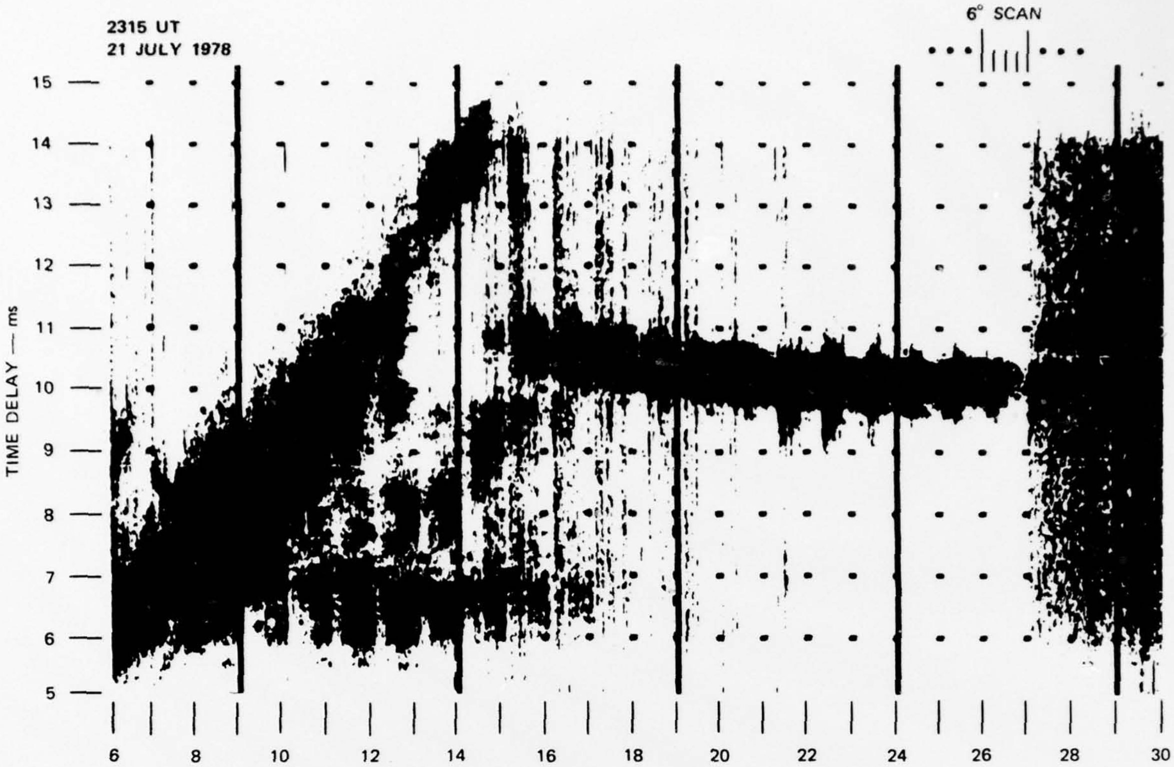


(a) ANALOG PROCESSED SOUNDING

SOUNDING FREQUENCY (MHz)	AZIMUTH (deg) 70		71		72		73		74		75		TOTAL CROSS SECTION (dBsm)
	CROSS SECTION (dBsm)												
16	67	69	70	72	72	73	75	69	76	--	--	--	79
17	67	67	69	69	68	70	67	--	72	--	69	71	76
18	65	65	65	61	61	66	71	72	74	70	73	72	78
19	60	62	62	62	64	64	63	65	63	56	61	60	70
20	50	51	52	55	52	57	59	58	56	53	57	53	63
21	51	55	54	59	58	62	61	64	60	54	60	56	67
22	48	52	55	56	58	60	66	67	66	57	64	59	70
23	53	56	58	65	64	65	68	70	66	56	61	61	72
24	59	60	61	72	72	70	70	74	69	58	61	62	77
25	62	65	64	68	71	69	57	62	59	50	53	57	73

(b) HEATER CLOUD CROSS SECTION PROFILE

FIGURE 6 HF SOUNDING SHOWING HEATING ECHOES (2215 UT, 21 July 1978, 6° scan)

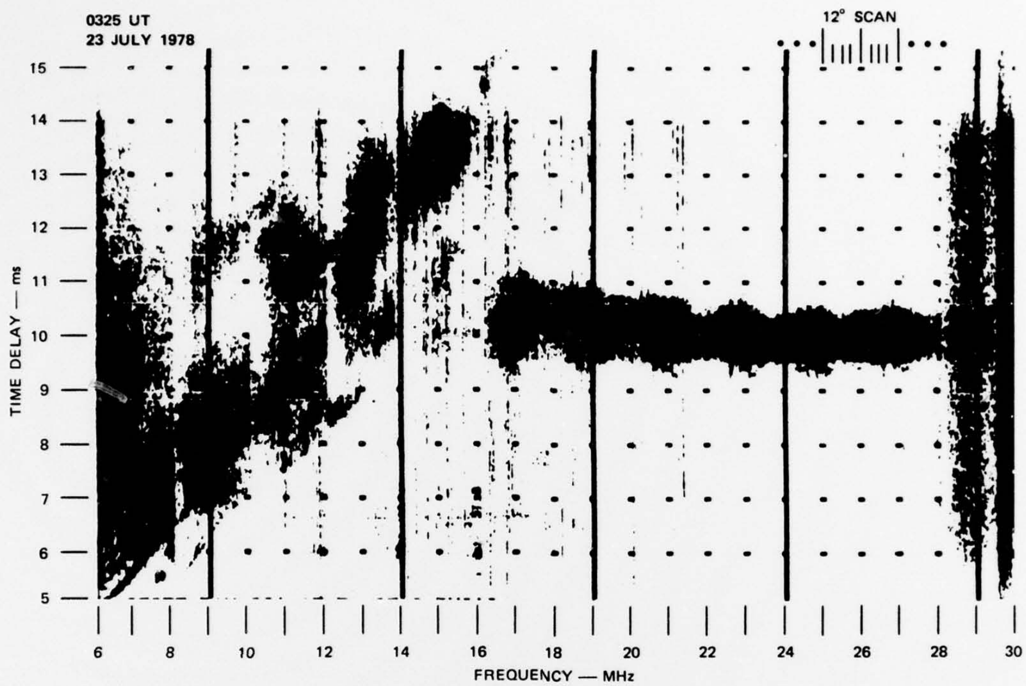


(a) ANALOG PROCESSED SOUNDING

SOUNDING FREQUENCY (MHz)	AZIMUTH (deg) 70		71		72		73		74		75		TOTAL CROSS SECTION (dBsm)
	CROSS SECTION (dBsm)												
16	64	65	66	65	65	64	66	68	67	65	69	64	74
17	61	63	64	64	63	66	66	69	68	64	67	64	73
18	57	57	59	57	60	61	63	63	69	63	65	62	71
19	53	55	57	58	59	62	65	64	68	58	61	59	70
20	52	55	55	61	61	63	67	68	69	61	65	62	72
21	56	57	57	56	61	61	60	63	65	56	61	56	68
22	48	54	52	56	61	62	65	66	67	59	65	61	70
23	52	54	55	57	61	62	68	69	66	59	63	62	71
24	56	62	66	68	67	69	72	76	67	60	59	63	76
25	60	63	63	72	70	72	64	75	68	62	65	63	77
26	64	69	67	74	71	75	53	57	58	53	55	64	75

(b) HEATER CLOUD CROSS SECTION PROFILE

FIGURE 7 HF SOUNDING SHOWING HEATING ECHOES (2315 UT, 21 July 1978, 6° scan)



(a) ANALOG PROCESSED SOUNDING

SOUNDING FREQUENCY (MHz)	AZIMUTH (deg) 67	68	69	70	71	72	73	74	75	76	77	78	TOTAL CROSS SECTION (dBsm)
	CROSS SECTION (dBsm)												
16	69 71	70 67	68 68	66 68	69 70	72 72	76 75	76 71	77 70	65 68	68 61	63 63	81
18	56 61	60 58	61 64	65 66	69 69	69 71	72 73	73 65	66 66	58 61	62 57	58 58	77
20	50 52	50 55	58 57	61 63	65 66	67 68	69 70	71 67	69 70	66 71	65 57	61 62	77
22	49 53	52 54	58 58	62 64	65 67	69 69	70 73	72 72	74 69	63 66	64 60	61 62	78
24	56 59	58 65	66 65	73 75	77 80	80 79	82 83	81 70	72 74	70 73	69 68	70 66	86
26	65 68	66 67	71 73	77 79	79 82	83 82	78 80	78 68	75 71	61 67	64 60	62 61	87

(b) HEATER CLOUD CROSS SECTION PROFILE

FIGURE 8 HF SOUNDING SHOWING HEATING ECHOES (0325 UT, 23 July 1978, 12° scan)

reflection, the peak echo appears to shift rapidly to the north. Although no explanation has yet been found for the 1° southern discrepancy, the rapid northward shift of the peak echo just before total echo extinction can be explained by ray-tracing analysis. Bubenik (1976) showed that as the radio frequency increases there comes a point where the criteria for specular reflection can no longer be met and the cloud ceases to reflect. For the WARF-Platteville geometry, specular reflection first ceases at the southern cloud boundary. Echo extinction then moves north as the sounding frequency increases, thus causing a shift in peak echo location.

B. September Heating Experiments

1. RTW Propagation

Several RTW propagation measurements were made, while the heater transmitter was cycled on and off. At 1605 UT on 22 September with Lost Hills transmitting westward on a bearing of 246°, a RTW signal was seen, from 16 to 22 MHz. The echo azimuthal arrival angles were 67° to 73° and the signal to noise ratios were 3 to 10 dB. When the Platteville heater was turned on for five minutes, the RTW signal strength increased ~4 dB, compared with the off periods before and after, but only for frequencies from 17 to 19 MHz and angles 67° to 71°. This increase in signal strength is at best a marginal detection of an effect. Records made in the following hour showed no discernable change between heater on and off.

2. Ava Direct

The multihop oblique-scatter signal from Ava, New York, to the Los Banos site was recorded with the Platteville heater on and off, and is shown in Figure 9. The ray paths go through or slightly north of the heated volume. An increase of 12-dB signal strength in the vicinity of the third hop was noted when the heater was on, compared to a measurement 5 min earlier. The signal was increased noticeably only between 13 and 14 MHz, which corresponds to the nose of the third-hop return. During this 5-min interval, other features of the oblique scatter record

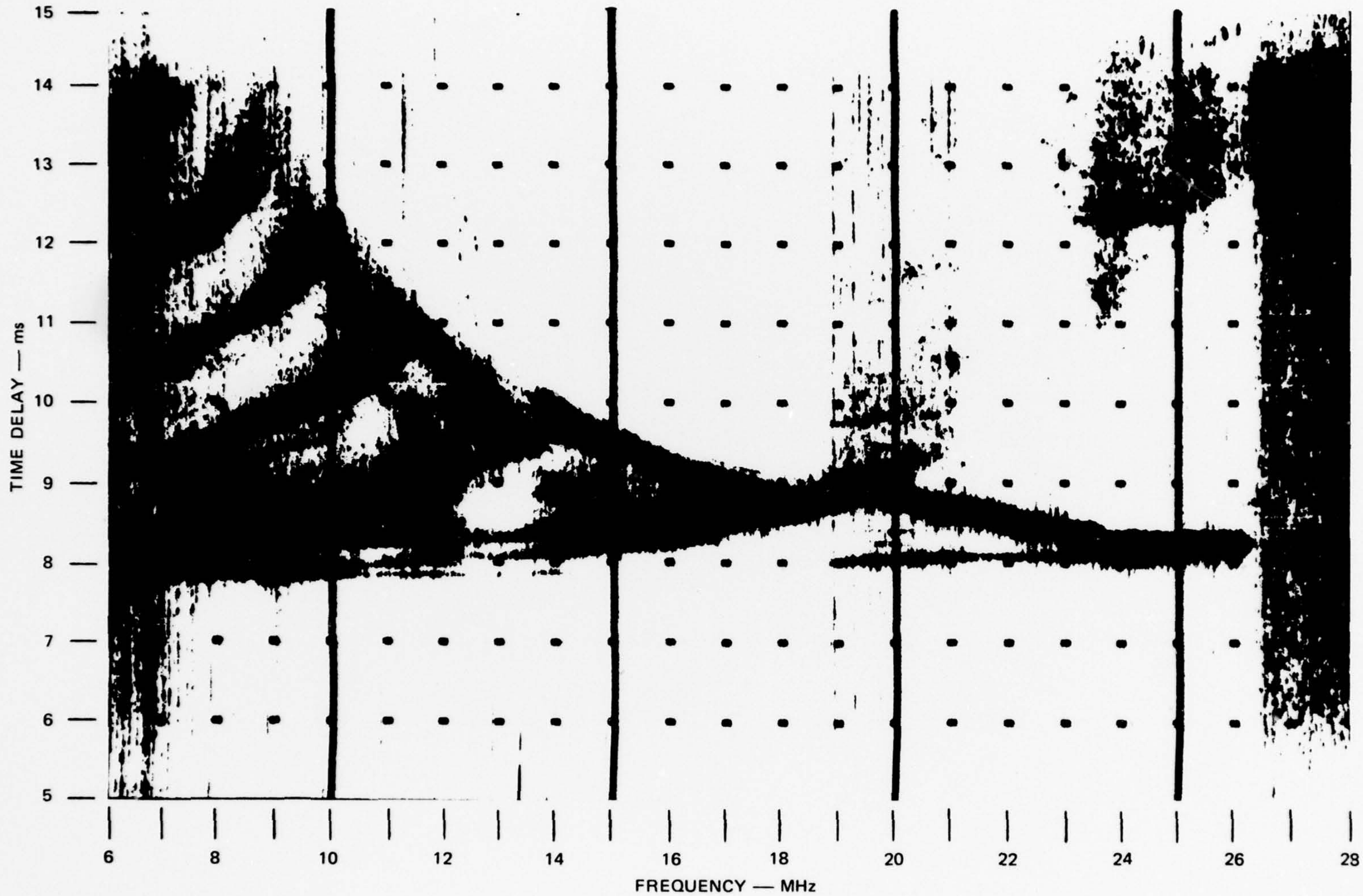


FIGURE 9 FORWARD SCATTERING: AVA TO LOS BANOS

changed in intensity by several decibels so that the detected difference has only marginal significance.

3. Beam Tilt

On one occasion, the Platteville heating beam was cycled in direction between vertical and a 30° northward tilt. The time at each beam position was five min, with a power of 1.46 MW and a frequency of 5.05 MHz. The WARF radar was swept in frequency from 6 to 30 MHz, with an angular coverage of 12°.

The heater cloud appeared distinctly from about 12 to 17 MHz on both beam positions, with a range extent of 300 km. If the cloud had a north-south extent also of 300 km, it would subtend 12° in the WARF beam. A 30° tilt at an altitude of 240 km would imply a change in the observed beam center position of 5°. No clear change could be identified between the vertical and tilted beam positions. At 14 to 16 MHz, both positions extended over the whole observed region (12° in extent). Small changes in intensity and range could have easily been caused by ionospheric propagation effects of the WARF interrogating beam.

4. Power Cycling

The HF heating power was cycled between 1.20 and 0.54 MW with two minutes at each power level. The HF frequency was 5.05 MHz and the WARF was operated in a narrow sweep made between 20.70 and 20.725 MHz. The total echo power of the cloud was measured, and the results are plotted in Figure 10. The difference in transmitted power is 3.5 dB, and the difference in echo power can be seen to be about 2 dB, indicating a saturation with increasing HF power of the process causing the scatter. The rapid fall-off in time at the end of the run is probably caused by changing propagation of the 20.70-MHz probing wave.

A similar experiment was carried out immediately after the above run with a pulsing scheme whereby one minute of CW was alternated with one minute of 25% duty factor transmission of 2.5-ms pulses. The echo strength was too weak to obtain meaningful results, possibly because the 20.70-MHz WARF transmission was not optimum.

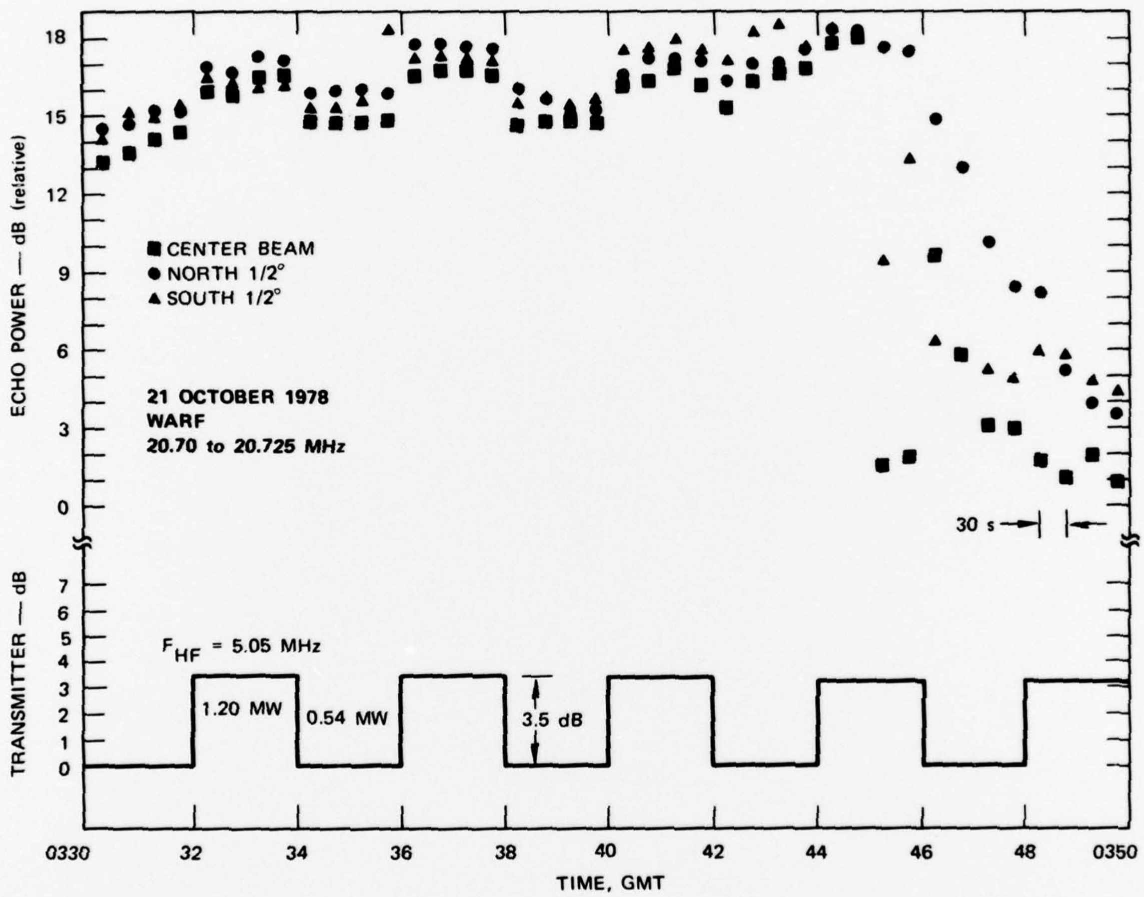


FIGURE 10 HEATER POWER CYCLING

IV FUTURE EFFORTS

The capability to measure the elevation angle is being added to the WARF facility and should permit more accurate determination of the absolute cross section of the FAS cloud, because the antenna gains are strongly determined by the elevation angle.

A swept-frequency transmitter (supplied by SRI International) is being installed in Salisbury, Australia. The transmitter will be used in a direct test of the feasibility of having the heated volume scatter elevated modes back to the ground. Elevated modes are modes that are detached from the ground and refract at varying altitudes within the ionosphere. Radio waves can enter elevated modes when horizontal gradients are present in the ionosphere. These gradients can occur across the day-night boundary, in the auroral region, or across the equatorial anomaly.

A swept-frequency transmission will be launched from Salisbury to the northeast (the bearings to Platteville and Los Banos are 65° and 63° respectively). As the wave propagates across the Pacific, hopefully it will enter into an elevated mode which would skip over California, intersect the heated region over Colorado, and be scattered back to Los Banos. The signals received at Los Banos will be discriminated by azimuth, time-of-arrival, and frequency, thus making possible identification of the various types of propagation paths.

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